REMARKS

Claims 1 - 34 are pending in the application. Currently, all claims stand rejected. By the present amendment, claims 1, 15, 21 and 24 - 34 have been amended.

Claims 25 - 33 were rejected under 35 U.S.C. § 112, second paragraph, as being indefinite.

Further, claims 1 - 4, 10, 16, 18, 20, 24 and 25 were rejected under 35 U.S.C. § 102(b) as being anticipated by Bucholtz (reference E: U.S. Patent No. 6,471,710). The Examiner contends that Bucholtz discloses a probe position sensing system comprising curvature sensors 42a, 42b, 42c, a bend member 47, optical fibers 50 and detection device 54. The Examiner further contends that element 41 functions as a coupling means.

Still further, claims 1 - 33 were rejected under 35 U.S.C. § 102(e) as being anticipated by Hay et al (reference A: U.S. Patent No. 6,278,811). The Examiner contends that Hay et al. disclose a fiber optic Bragg grating pressure sensor comprising a bend member 12, optical fiber 28,30 and detection device 35. The Examiner contends that Hay et al. teach the optical fiber Bragg grating laser, the pair of rigid pieces and a mount assembly (FIG. 4) and a serpentine configuration in FIG. 8.

Additionally, claims 5 - 9, 17, 19, 22 and 23 were rejected under 35 U.S.C. § 103(a) as being unpatentable over Bucholtz in view of Hay et al. The Examiner contends that Bucholtz

discloses every aspect of the claimed invention except for at least one detection device having more than one optical fiber Bragg grating or fiber Bragg grating laser embedded in each of the optical fibers. The Examiner contends that Hay et al. disclose fiber optic Bragg grating pressure sensor having at least one detection device having more than one optical fiber Bragg grating or fiber Bragg grating laser embedded in each of the optical fibers. The Examiner contends that it would be obvious to modify Bucholtz's device to have at least one detection device having more than one optical fiber Bragg grating or fiber Bragg grating laser embedded in each of the optical fibers for the purpose of detecting physical properties at different locations without having extra separate detection device or optical fiber.

With regard to claims 7, 8, 19 and 23, the Examiner contends that Bucholtz discloses every aspect of the claimed invention except for the optical fiber Bragg grating laser. The Examiner contends that Hay et al. disclose a fiber optic Bragg grating pressure sensor having an optical fiber Bragg grating laser. The Examiner contends that it would be obvious to modify Bucholtz's device to have the optical fiber Bragg grating laser for the purpose of variable lasing wavelength.

Claims 11 - 15 and 21 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Bucholtz in view of Hay et al. The

Examiner contends that Bucholtz discloses every aspect of the claimed invention except for the pair of rigid pieces and a mount assembly. The Examiner contends that Hay et al. disclose a finer optic Bragg grating pressure sensor having the pair of rigid pieces and a mount assembly. The Examiner contends that it would be obvious to modify Bucholtz's device to have the pair of rigid pieces and a mount assembly for the purposes of hermetical sealing of the optical fiber sensor and the housing.

Claim 34 was rejected under 35 U.S.C. § 103(a) as being unpatentable over Bucholtz in view of Danisch (reference F: U.S. Patent No. 6,127,672). The Examiner contends that Bucholtz discloses every aspect of the claimed invention except for the roll sensor. The Examiner contends that Danisch teaches at column 11, lines 8 - 22 that combination of roll sensors. The Examiner contends that it would be obvious to modify Bucholtz's device to have the roll sensor for the purpose of accurate information of the property change in the device.

Claim 34 was rejected under 35 U.S.C. § 103(a) as being unpatentable over Hay et al. in view of Danisch. The Examiner contends that Hay et al. disclose every aspect of the claimed invention except for the roll sensor. The Examiner contends that Danisch teaches at column 11, lines 8 - 22 that combination of roll sensors. The Examiner contends that it would be obvious to modify Hay et al.'s device to have the roll sensor for the

purpose of accurate information of the property change in the device.

The foregoing rejections are respectfully traversed in view of this amendment.

The present invention relates to a system for detecting curvature in a towed hydrophone array. The system comprises at least two curvature sensors positioned along the length of the towed hydrophone array; each of said curvature sensors comprising a bend member which bends as the array bends, at least one optical fiber within the bend member, and at least one detection device embedded within said at least one optical fiber to detect a change in strain in said at least one optical fiber; and means for limiting the bending of said at least one optical fiber.

In another aspect, the present invention relates to a curvature sensor which comprises a bend member; at least one optical fiber within the bend member; at least one detection device embedded within said at least one optical fiber to detect a change in strain in said at least one optical fiber; and means for limiting the bending of said at least one optical fiber.

In yet another aspect, the present invention relates to a system for determining the curvature and shape of a towed hydrophone array. The system comprises a plurality of curvature sensors positioned along the length of the towed hydrophone

array; each of said curvature sensors comprising a bend member which bends as the array bends, at least one optical fiber within the bend member, at least one detection device embedded within said at least one optical fiber to detect a change in strain in said at least one optical fiber, and means for limiting the bending of said at least one optical fiber; and a plurality of roll sensors positioned along the length of the towed hydrophone array with each of said roll sensors being in close proximity to a respective one of aid curvature sensors.

It is submitted that none of the cited and applied references teach or suggest the various claimed features of the present invention.

With regard to the rejection of claims 25 - 33 under 35 U.S.C. § 112, second paragraph, the error arose due to a typing error relating to the dependency of the claims. By the present amendment, the dependency of claims 25 - 33 have been changed. As a result, this rejection has been obviated.

With regard to the anticipation rejections over Bucholtz and Hays et al., it is submitted that neither of these references teaches or suggests the claimed invention. In particular, neither of these references has any relationship to a curvature sensor used within a towed hydrophone array. Additionally, neither of the cited and applied references

discloses or suggests a means for limiting the bending of the optical fiber(s).

Bucholtz presents an entirely different application. Key differences are that the Bucholtz invention has rigid sections connected by flexible elbows, whereas the present invention has a towed hydrophone array which is continuously flexible. Also, the Bucholtz device has very large bending angles at each flexure location, probably 90 degrees or more. By contrast, the present invention must measure bending that is much less than a degree. Thus, there is a great difference in the accuracy required by the two inventions.

One of the key aspects of the present invention is the claimed bend limiting means. This feature is not included in Bucholtz. Bucholtz states in column 10, lines 21 to 34: "[h]ence, it is possible to design the flexible joint 38 such that, although the strain in the joint material is larger than a few percent, the strain in the strand 56 is safely less than a few percent. This safety arrangement can be at the expense of the reduced angle accuracy at small bend angles. Conversely, the flexible joint materials may be chosen such that the strain efficiency is nearly unity but then care should be taken to restrict the bend angles to values small enough to prevent mechanical failure of the strands 56. In addition ... the strain experienced by the strands 56 depends on the location of

the strands relative to the neutral bend axis 61 of the joint 38." Thus, Bucholtz points out the basic problem without ever solving it. The fiber strain must be held to less than a few percent in order to not break the fiber.

One gets to choose how efficiently bending strain is transmitted to the fiber by choosing how far the fibers are located from the neutral axis. However, if one chooses to keep the fibers safe during large bends, one loses sensitivity. If one chooses to arrange the fibers for maximum sensitivity, the fibers may break if the device is bent too far. In the present invention, this tradeoff is overcome by development of the bend limiting means. This means allows the fiber to be positioned for maximum sensitivity to small bends, but stops the bending of the fiber carrying bend member at large bends, without keeping the full array from being so bent. The result is that the fiber sensor elements function only over the necessary bending range, while allowing the array a greater bending range for array storage, during which position readout is not required. The advantage is greater sensitivity to small bends, something that was not a great concern in Bucholtz's system.

The bend limiting means has another major advantage. It is desirable to multiplex a number of such bend sensors on a single fiber. If each bend sensor has at least three grating sensors and the serpentine configuration is used, the number of sensors

per fiber is further increased. The best mechanism to multiplex these sensors is to use wavelength division multiplexing, whereby each sensor operates at a unique wavelength. Specifically, each sensor operates over a unique wavelength range because the wavelength changes as the array curvature changes at that location. There is generally a limited wavelength range available. This total range, divided by the wavelength range of each sensor, sets the total number of sensors allowed per fiber. It is clear that reducing the wavelength range of each sensor will allow more sensors to operate on the fiber. However, since there is a limitation on the accuracy with which a small wavelength shift can be read, changing the sensors strain efficiency to limit the wavelength range also limits the ability to measure small bending angles. The bend limiter feature limits the range of strains seen by the fiber grating sensor and thus limits the wavelength range as well. It does so while allowing the highest strain sensitivity for good sensitivity to small bends.

With regard to the Hays et al. reference, the Examiner has misinterpreted some of its features. Most notably, part 12 in Hays et al. is not actually a bend member. It is meant to strain longitudinally, not bend. The comparison of Figure 4 to the present invention is unwarranted. Figure 4 does not teach or suggest any of the claimed features. As for Figure 8 of Hays

et al., this figure does not show a serpentine configuration. Rather, it shows a sensor fiber spirally wound around a mandrel. It does not show two gratings on this spiral. However, these are not independent sensors but two gratings forming a single laser sensor. The spiraled fiber is thus part of the sensing fiber of the detector. In the present invention, the purpose of the serpentine configuration is to connect independent grating or fiber laser sensors on a single fiber. The sensors are configured to be straight down the axis of the bend member and the serpentine fiber is just interconnecting fiber between the straight sensor sections.

Thus, independent claims 1, 24, and 34 are allowable because Bucholtz and Hays et al., alone or in combination with each other, do not teach or suggest incorporating the curvature sensor into a towed hydrophone array as set out in claims 1 and 34 and/or the bend limiting means of claims 1, 24, and 34. With regard to claim 34, Danisch does not cure the deficiencies of Bucholtz and Hays et al. Claims 1, 24, and 34 are further allowable over Hays et al. because Hays et al. does not teach or suggest the claimed bend member.

Claims 2 - 23 and 25 - 34 are allowable for the same reasons as their parent claims as well as on their own accord. For example, it is submitted that neither Bucholtz nor Hays et al. teaches or suggests the radially distributed optical fibers

of claims 3 and 32, the coupling means of claims 10 and 11, the bend rod within the mount assembly of claim 12, the mount assembly structure of claim 13, the internal stringers of claim 14, the bend limiting means set out in claims 15 and 21, the serpentine configuration of claims 17 and 29, and the bend cylinder of claims 20 and 33.

For the foregoing reasons, the instant application is believed to be in condition for allowance. Reconsideration and allowance of this application therefore earnestly solicited.

In response to the Examiner's objections, the claims have been amended to the rewritten version above. Attached hereto is a marked-up version of the amended claims, in which the words between brackets are being removed and those words underlined are being added. The attached version is entitled **MARKED-UP VERSION OF AMENDED CLAIMS.**

The Examiner is invited to phone Michael F. Oglo, Attorney for the Applicants, 401-832-4736, if in her opinion, such phone call would serve to expedite the prosecution of the subject patent application.

Respectfully submitted,

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MARKED-UP VERSION OF AMENDED CLAIMS

1. (Amended) A system for detecting curvature in a towed hydrophone array, said system comprising:

at least two curvature sensors positioned along the length of the towed hydrophone array; [and]

each of said curvature sensors comprising a bend member which bends as the array bends, at least one optical fiber within the bend member, and at least one detection device embedded within said at least one optical fiber to detect a change in strain in said at least one optical fiber; and

means for limiting the bending of said at least one optical fiber.

15. (Amended) A system according to claim 11 [further comprising] wherein said bend limiting means comprises a gap between an outer surface of said bend rod and inner surface of said mount assembly and said gap being selected so that at a certain maximum curvature the bending of the bend rod is limited by the mount assembly and so that the optical fibers and the

detection devices experience no further strain at smaller bend diameters.

21. (Amended) A system according to claim 19 [further comprising] wherein said bend limiting means comprises: a mount assembly inside said bend cylinder; a gap between an inner surface of said bend cylinder and an outer surface of said mount assembly; and said gap being sized to limit the bending of said optical fibers.

24. (Amended) A curvature sensor comprising:

a bend member;

at least one optical fiber within the bend member; [and]

at least one detection device embedded within said at least one optical fiber to detect a change in strain in said at least one optical fiber; and

means for limiting the bending of said at least one optical fiber.

25. (Amended) A curvature sensor according to claim [23] 24 wherein said at least one detection device comprises an optical fiber Bragg grating.

26. (Amended) A curvature sensor according to claim [23] 24 wherein said at least one detection device comprises an optical fiber Bragg grating laser.

27. (Amended) A curvature sensor according to claim [23] 24 wherein each said optical fiber has a plurality of detection devices embedded therein.

28. (Amended) A curvature sensor according to claim [26] 27 wherein each of said detection devices operates at a different wavelength.

29. (Amended) A curvature sensor according to claim [23] 24 wherein each said optical fiber has a plurality of detection devices embedded therein.

30. (Amended) A curvature sensor according to claim [28] 29 wherein each of said legs has a detection device incorporated therein.

31. (Amended) A curvature sensor according to claim [23] 24 wherein said bend member comprises a bend rod and wherein said curvature sensor has at least three optical fibers embedded within said bend rod.

32. (Amended) A curvature sensor according to claim [30] 31 wherein said bend rod has a length and each of said optical fibers runs longitudinally down the length of the bend rod and wherein said optical fibers are radially distributed around the perimeter of the bend rod.

33. (Amended) A curvature sensor according to claim [23] 24 wherein said bend member comprises a bend cylinder and wherein said curvature sensor has a plurality of optical fibers embedded within said bend cylinder.

34. (Amended) A system for determining the curvature and shape of a towed hydrophone array comprising:

a plurality of curvature sensors positioned along the length of the towed hydrophone array;

each of said curvature sensors comprising a bend member which bends as the array bends, at least one optical

fiber within the bend member, [and] at least one detection device embedded within said at least one optical fiber to detect a change in strain in said at least one optical fiber<u>, and means for limiting the bending of said at least one optical fiber</u>; and

a plurality of roll sensors positioned along the length of the <u>towed hydrophone</u> array with each of said roll sensors being in close proximity to a respective one of aid curvature sensors.